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DRAWINGS ATTACHED

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THE PATENT OFFICE LONDON

## (54) METHOD FOR BONDING A WIRE TO A METAL LAYER

(71) We, HITACHI LIMITED, of 1-5-1 Marunouchi, Chiyoda-ku, Tokyo, Japan, a Japanese Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method for bonding a conductive wire to a metal layer formed on a substrate, in particular to a conductor, for example an electrode terminal formed on a semiconductor or insulating substrate.

There are several general methods for connecting a metal wire to an electrode of a semiconductor device: for example, a thermo-compression bonding method wherein a metal wire, such as one of gold, and a bonding area of, for example, an aluminum electrode are heated and pressed together; and an ultrasonic bonding method wherein a metal wire is pressed on the bonding area of an electrode with predetermined force and ultrasonic vibration is applied thereto. However, there may be disadvantages in applying these methods to bonding a wire to an electrode formed on a relatively weak substrate of a semiconductor element, since mechanical breakdown such as cracks can be caused to the substrate by stress under high pressure, and under low pressure the bonding may be incomplete. Also the above-mentioned methods are not necessarily applicable to all situations.

For example, in a hybrid integrated circuit device an interconnection layer comprising a metallized layer formed on an insulating substrate by a printing technique generally involves a material such as glass in metal powder, so that a metal wire cannot be bonded firmly to such a device by the above-mentioned thermo-compression bonding or the ultrasonic bonding methods. In this case, metal, for example gold, may be selectively deposited on the bonding area of the metallized layer by a plating or evaporating technique in order to allow firm connection of the metal wire to the metallized layer by thermo-compression bonding or ultrasonic bonding methods. But there is a disadvantage that an additional plating or evaporating step is needed, which may complicate manufacture.

A bonding method applied to a metal electrode of low melting point (hereinafter referred to as a solder electrode) may have advantages in that the bonding strength is strong and a relatively thick metal wire can be used, compared with the above-mentioned bonding methods. The bonding method is also applicable to the interconnection of high power circuit semi-conductor devices. There are several methods for bonding a metal wire to a solder electrode, for example:

(1) A metal lead wire may be directly connected, or connected through a metal wire known as a connector wire, to an alloy electrode of an alloy junction type transistor or a metal wire may be disposed between the solder electrode and the lead wire, and both the metal wire and the electrode are heated, by a hydrogen flame etc. to melt the alloy or the solder when the metal wire is in contact with the electrode.

(2) A solder layer may be formed on a metallized interconnection layer, as in a hybrid integrated circuit device and the like, and a metal wire which extends between each bonding area contacted therewith, and soldered in the way as that is usual with electronic parts.

(3) In an alloy junction type transistor a metal wire may be previously sunk into an electrode by using a capillary tube, and the electrode heated by a hot blast or for example a hydrogen flame to bond the metal wire thereto.

(4) An electric current may be applied to a metal wire to generate heat due to the resistance of the wire and the heat conducted to a solder electrode, thereby the metal wire is sunk into the solder electrode as the electrode melts.

However, method (1) may need a relatively long time for bonding since the whole bonding area and a portion adjacent thereto have to be heated, and there is the fear that

the relative position of the solder electrode and the metal wire could change; method (2) requires separate bonding steps for each join, therefore, the operation is complicated; method (3) needs a hot blast heating device and a hot blast heating step, and the operation therefore is complicated; and in method (4) it may be difficult to apply the electric current to a lead wire of low resistivity and to an extremely thin metal wire as the thermal conduction to the bonding area is bad, so that the application of the method is limited since the applied electric power is restricted. Therefor, it is difficult to apply method (4) except to an alloy junction type transistor wherein the metal is of a material such as nickel having high resistivity and having a thick cross sectional.

It is an object of the invention to go towards obviating some of the above-mentioned disadvantages.

According to the present invention there is provided a method for bonding a conductive wire to a metal layer formed on a substrate including the steps of guiding the wire through the passage of a capillary tube, pressing a portion of the wire extending from the capillary tube onto the metal layer by means of the capillary tube and heating the capillary tube to a temperature lower than the melting point of the wire but high enough to cause melting of the metal layer at the bonding area thereof, whereby said portion of the wire is pressed into the metal layer while metal of the metal layer is melted, cooling the metal layer so as to bond the wire to the metal layer, and then moving the capillary tube away to leave the said portion of the wire bonded to the metal layer.

Particular embodiments of the invention will now be described by way of example with reference to the accompanying drawings, wherein:—

Figs. 1(a) to (c) are cross-sectional views of a capillary tube and a bonding area illustrating various steps in one embodiment, and

Figs. 2(a) and (b) are cross-sectional views of a capillary tube and a bonding area according to another embodiment.

In Figs. 1(a) to 1(c) of the drawings, there is shown part of a semiconductor device, e.g. a hybrid integrated circuit device, which part includes an insulating substrate 1 such as a ceramic, an electrode or an interconnection layer 2 formed on the substrate 1 by a printing technique and a metal layer 3 consisting of lead and tin alloy solder formed so as to cover the electrode 2. A guide, which is a capillary tube 4, having a tapered end portion is provided for a metal wire 5, of silver, which is guided through the passage of the capillary tube 4. An end portion 6 of the metal wire 5, a so-called nail head, extends from the capillary tube 4. A nozzle 7 of a cooling device for solidifying the melted solder layer 3 is provided as seen in Fig. 1(b). In addition, the capillary tube 4 has resistance heating means for heating it to a predetermined temperature disposed at an upper part (not shown in the Figures) and the tube 4 is composed of an alloy to which the solder does not adhere. The nail head 6 of the metal wire 5 is formed by burning off the metal wire 6 in a hydrogen flame. A moving mechanism of the capillary tube is the same as that for moving the parts together in a usual thermocompression bonding method.

The capillary tube 4 is positioned so as to dispose the nail head 6 above a predetermined bonding area of the solder layer 3 as shown in Fig. 1(a), and is heated up to a temperature which is lower than the melting point of the wire 5 but not lower than the melting point of the solder layer 3 by the resistance heating means so as to melt the metal of the metal layer 3 in the bonding area when the head 6 is pressed onto the solder layer 3 by the capillary tube 4.

The temperature may be fixed at any temperature not lower than the melting point of the solder layer 3, but in the case of a temperature close to the melting point, it takes a longer time for bonding to occur. A temperature higher than the melting point of the solder by 20°C to 100°C is effective. For example, in the embodiment a solder whose eutectic point is 220°C was used and the temperature of the capillary tube 4 fixed at 300°C. The substrate 1 or the solder layer 3 do not particularly need to be heated overall, they may be kept at room temperature, but can be heated to a higher temperature up to just below the melting point of the solder so as to soften the solder, although melting is still caused by heat from the capillary tube 4. For example, the substrate 1 may be heated to 100°C.

Then as shown in Fig. 1(b), the capillary tube 4 is lowered and the nail head 6 of the silver wire 5 is pressed onto the solder layer 3 by the tapered end of the capillary tube 4.

In this step the nail head 6 is heated to a temperature not lower than the melting point of the solder layer 3 by heat conducted from the capillary 4 and is pressed onto the solder layer 3 under a predetermined load so that the nail head 6 is buried in the solder layer 3 as the portion of the solder layer 3 which the nail head 6 contacts is melted. The load applied to the bonding area by the capillary tube 4 can be selected since the load causes no influence on the bonding strength but only varies the time taken for bonding. As the load is increased, the time taken for the bonding is shortened. For example, in the case of a silver wire of 125 microns diameter, the load is selected

to be about 200 grams. In this way, the load is applied until the whole nail head 6 is buried in the solder layer 3 or the tapered end of the capillary tube 4 is also slightly buried in the solder layer 3, and then cooling gas is directed onto the bonding area from nozzle 7 to solidify the solder.

Then as shown in Fig. 1(c), the capillary tube 4 is pulled up, while the wire is clamped relative to the substrate above the upper part of the capillary tube so as to prevent excessive force being applied to the bond. The clamping means (not shown) is used to prevent the destruction of the bond by large tension applied to the silver wire when pulling up the capillary tube. For example, the clamping may involve holding the wire between two boards with suitable pressure so as to utilize friction, but a special clamping means is not always needed where no large tension is applied to the metal wire 5. In this case the nail head 6 of the silver wire 5 is left bonded in the solder layer 3 when the capillary tube 4 has been removed.

The above described method can be applied to the case wherein a semiconductor substrate is used in place of the ceramic substrate 1 and a metal wire is bonded to a solder layer such as a solder layer formed on an electrode on the semiconductor substrate, or to a metal electrode of a low melting point in an alloy junction type transistor or a printed substrate.

Figs. 2(a) and (b) illustrate another embodiment of this invention wherein after the metal wire has been bonded to a portion of a solder electrode on a semiconductor substrate in the above-described manner, the capillary tube 4 is moved upward and towards another position over the solder layer 3 formed on metallized layer 2 on the substrate 1 without meanwhile cutting the silver wire 5 to bond the silver wire 5 to the solder layer 3 in another position.

In Fig. 2(a), the capillary tube 4, heated up to a temperature lower than the melting point of the wire 5 but not lower than the melting point of the solder layer 3, is brought adjacent to the surface of the solder layer 3, then the hook shape portion 9 of the wire 5 which extends from the end of the capillary tube 4 is pressed onto the solder layer 3 by the capillary tube 4 and is buried in the solder layer 3 as the solder is melted, and then cooling gas is directed onto the bonding area from the nozzle 7.

After the wire 5 is bonded, the capillary tube 4 is moved away and the wire 5 is burned off by a hydrogen flame 10 as shown in Fig. 2(b) to leave two ends 6, $6^1$.

In this way, an interconnection between electrodes by the metal wire can be made.

The bonded portion of the metal wire and the solder layer in the above embodiments have the same strength as the breaking strength of the wire so that a good bonding strength is obtained, since the end portion of the silver wire is buried in the solder layer without causing a change of shape thereof. Also the method can be performed quickly, easily and efficiently.

Also, since a device the same as may be used in previous thermo-compression bonding processes may be used for the embodiments and the temperature for the method can be made uniform by properly selecting a metal layer of low melting point, the method may be used together with other methods. For example, a thermo-compression bonding method may be applied to a wire and an electrode in a device to which a heavy load for the thermo-compression bonding can be applied and the above-described bonding method may be applied to bond the wire to another electrode to which it is difficult or undesirable to apply the thermocompression bonding method.

As explained above, the embodiments according to the invention can be extremely easily performed by heating a capillary tube up to a temperature not less than the melting point of the solder but less than that of the wire without fear of applying too big a stress to a bonding area.

Further the methods described above have the advantage that, for example, a thermo-compression bonding device can be used by itself as the operating device.

Although silver is used as a conductive wire in the above embodiments, a wire consisting substantially wholly of gold or substantially wholly of silver for example, may be used instead of silver, if required.

WHAT WE CLAIM IS:—

1. A method for bonding a conductive wire to a metal layer formed on a substrate including the steps of guiding the wire through the passage of a capillary tube, pressing a portion of the wire extending from the capillary tube onto the metal layer by means of the capillary tube and heating the capillary tube to a temperature lower than the melting point of the wire but high enough to cause melting of the metal layer at the bonding area thereof, whereby said portion of the wire is pressed into the metal layer while metal of the metal layer is melted, cooling the metal layer so as to bond the wire to the metal layer, and then moving the capillary tube away to leave the said portion of the wire bonded to the metal layer.

2. A method according to claim 1, wherein the conductive wire consists substantially wholly of silver and the metal layer is of solder.

3. A method according to claim 1, wherein the conductive wire consists substantially wholly of gold and the metal layer is of solder.

4. A method according to any one of the preceding claims wherein the metal layer is on an electrode formed on a semiconductoir substrate.

5. A method of bonding a conductive wire to a metal layer substantially as herein described with reference to and as illustrated in Figs. 1(a) to 1(c) or Figs. 2(a) and 2(b) of the accompanying drawings.

6. A device including a conductive wire bonded to a metal layer by a method according to any one of the preceding claims.

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FIG. 1a

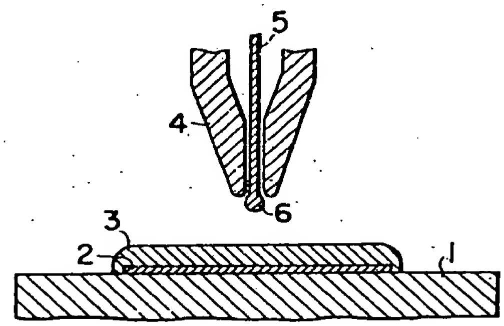


FIG. 1b

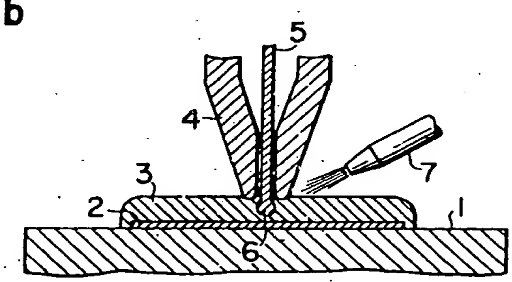


FIG. 1c

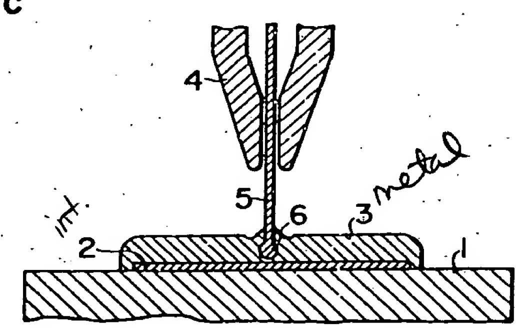

FIG. 2a

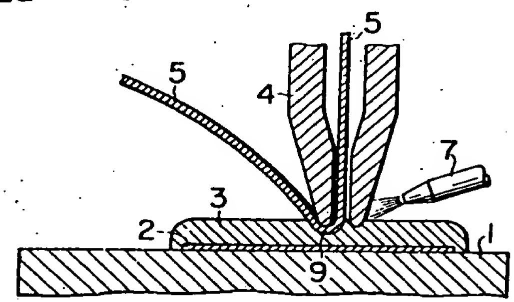


FIG. 2b